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Online Touchless Palmprint Registration System in a Dynamic Environment

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Abstract

In this paper we proposed a novel method to acquire the ROI (Region of interest) from touchless palmprint captured from a web camera in real time. A new algorithm is used to find the candidate key points of hand roughly and quickly. An improved method is used to capture maximum ROI using these key points along with finger width to get maximum ROI of the palm. The results show that approach is robust and efficient in color palmprint images which are acquired in different lighting conditions, cluttered background, different palm orientation and scaling effect.

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Keywords: Palmprint; Region of Interest (ROI); Skinlikelihood; Touchless; Valley points.

1. Introduction

Biometric based recognition systems have wide applications in the field of personal identification/verification. Fingerprint based systems are most widely used while iris based systems are considered to be most reliable. The palmprint is the region between the wrist and fingers. It has features such as texture, wrinkles, principle lines, ridges and minutiae points that can be used for its representation. The use of palmprints over other biometric technologies has several advantages. Firstly, the print patterns are unique, and the palm characteristics are more abundant than fingerprint and iris. Secondly, the iris patterns required high resolution images while the palmprint recognition uses the principal lines and wrinkles which are also discriminating in low-resolution images. So the capture device is less expensive than iris recognition. Moreover, palmprint recognition system presents much higher user acceptability than iris and fingerprint. Most current palmprint recognition systems have a complex device for controlling the background and light, and hand position. These systems are much larger than fingerprint recognition system. The users must put their hand in the semi-enclosed box, on the sensor or a plate with pegs. It makes user very uncomfortable during identification and causes sanitary issue in the public areas. These reasons greatly limit the application of the palmprint recognition system. So it is very beneficial to design a novel system to process the touchless and unsupervised hand image for palmprint registration (accept or reject palm image that merit further processing) considering the following factors:

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- Scaling Effect: Palm at varying distances from the axis of camera.
- Rotation: Palm in different orientation.
- Cluttered Background: Segmenting palm image from complex background.

In Touchless palmprint registration system users need not touch their palm on a scanner or any complex devices that restrict them to have their palm in a certain pose and make them feel uncomfortable. The ROI from the palmprint of user can be captured in Touchless mode from the low resolution CCD camera. The user simply puts their palm in front of camera without much restrictions.

2. Related Work

Palmprint acquisition process is the very first and key step for developing fast and durable online palmprint recognition system. Ink-based palmprint images had been used in earlier studies[1,2] where the palmprints were inked to paper and digitized using scanner. This two-step process was slow and not worthy for the online palmprint recognition system. However, various input sensor technologies like flatbed scanner, CMOS camera, CCD camera and infrared sensor have been developed for direct acquisition of palmprint. Among these technology scanners and CCD camera are most frequently using input devices[3,4]. Scanner and CCD camera provides high quality of images with little loss of information but scanner takes some time (few seconds) for image acquisition and this delay could not address the requirements of the online palmprint recognition system. Zhang *et al.* (Zhang *et al.*, 2003)[5] suggests to use a CCD camera in a controlled environment and reported good results. Michael Goh Kah Ong (Michael Goh Kah Ong., 2008)[6] has proposed the use of a low-resolution webcam for ROI acquisition in real-time system but in semi-controlled environment, considering only the effect of background images. But still there are various other factors, that are needed to be considered like scaling effect, rotation etc. while capturing the ROIs from the real-time video frames.

3. Proposed Methodology

In order to solve the problems that touchless palmprint system is facing, we attempt to propose the basic building blocks which use the following methods:

- A Gaussian skin color model is used to reduce effect of background images and Segment the hand image.
- A novel valley detection algorithm is used to find valley locations. An improved method is used to capture maximum ROI using these valley points along with finger width.
- Area of convex hull (polygon formed by joining extreme boundary pixels) is used to reduce scaling effect.
- slope of line joining two valley points $V1$ and $V3$ is used to correct the palm in different orientations.

In this paper, we proposed essential building blocks to develop a touchless palmprint registration system which can capture hand images in a touchless environment. These building blocks would make the system more robust and sensitive to different background images, different palm orientation, different lightening conditions and scaling effects without the additional sensor cost or adding user complication. The users do not need to touch or hold on to any peripheral for their hand images to be acquired. When their hand images are captured, the ROI of the palm will be tracked and extracted under all these dynamic environment.

4. Building Blocks

4.1 Skin-color model

Skin Color of hand has proven to be a useful and robust cue for hand detection and tracking and carry relatively stable information on hand. It is different from most of the background color. In order to segment the hand from the background based on skin color, we need a reliable skin color model. It has been shown in the researches, skin colors of different people are very close, but they differ mainly in intensities. The skin classification based on the Gaussian skin color model have been used much in the previous work[7,8]. One advantage of the Gaussian skin color model is that they can be made to perform reasonably well even in small amounts of training data. Therefore, a skin color

Fig. 1. Sample images with each resized to 16 × 16.

distribution can be represented by Gaussian distribution[9]. The mathematical expression of a Gaussian distribution is shown below (2). For this we have taken 16 small skin sample images (see Fig. 1) of 16 × 16. The sample images are converted from RGB to YCbCr color space. Then we compute the covariance matrix and means by (1) for both Cb and Cr components in order to fit the data into Gaussian Model

$$\text{Mean: } m = E\{x\}, \quad \text{where,} \quad x = \begin{bmatrix} cb \\ cr \end{bmatrix}$$

$$\text{Covariance: } C = E\{(x - m)(x - m)^T\} \tag{1}$$

Through calculation of the samples, the values of m and C are in the following:

$$\text{Cbmean} = 148.0218$$

$$\text{Crmean} = 99.1442$$

$$\text{Covariance(C)} = \begin{pmatrix} 313.115 & 195.065 \\ 195.065 & 271.989 \end{pmatrix}$$

Therefore, likelihood of any pixel with its chromatic pair value (cb, cr) obtained by transforming each pixel from RGB color space to chromatic color space) can then be computed by (2):

$$S(x_i) = P(cb, cr) = \exp(-0.5 \times x_i^T \times C^{-1} \times x_i)$$

$$\text{where,} \quad x_i = \begin{pmatrix} cb_i - cbmean \\ cr_i - crmean \end{pmatrix} \quad \text{and,} \quad S(x_i) \text{ is skin-likelihood of pixel } x_i. \tag{2}$$

The skin-likelihood image thus obtained is the gray scale image whose gray values represents the likelihood of the pixel belonging to the skin. A sample color image and its resulting skin-likelihood image are shown in Fig. 2. All skin regions (like a palm) are shown brighter than the non-skin region. The edges of the likelihood image are then detected. With appropriate thresholding, the gray scale images can then be further transformed into a binary image showing skin regions and non-skin regions. The binarized image is then overlapped with the detected edge and then we apply morphological filling, erosion and dilation operations in the same order to separate the skin areas that are loosely connected to remove noisy regions around the skin-color region. The resulting image is then processed with circular averaging filter for getting smooth boundary of the palm. The segmented image resulting from this technique is shown in Fig. 2. The overall steps for detecting palmprint from a cluttered background using the Gaussian skin color model are described in Algorithm 1.

4.2 Valley points detection

The Valley Points (VP) Detection is the key step towards the ROI extraction. As the ROI is extracted on the basis of these valley points, the precision and accuracy of VPs (see Fig. 3) play an important role in getting better and more

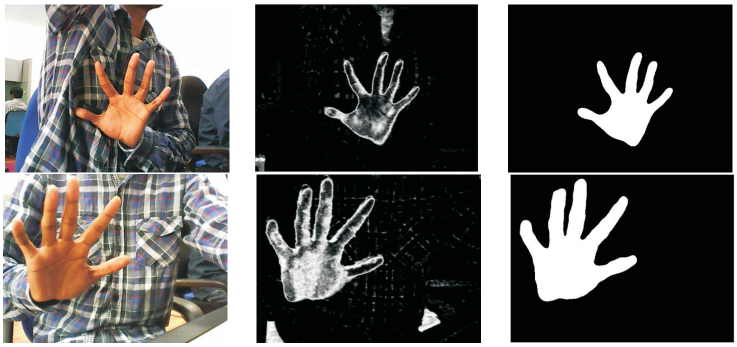

Fig. 2. The original palm in complex background (Leftmost) and corresponding skin-likelihood of the palm (Middle), skin-segmented palm (Rightmost)

Input: Read the input covariance(C) and mean(Cbmean, Crmean) of Cb and Cr component of sample image.
Output: DetectedPalm

while camera_input **do**
  img← AcquireFrame(camera)
  M← rows(img)
  N← columns(img)
  YcbcrImg ← imycbcr(img).
  skinLikelihood ← $ZeroMatrix_{M,N}$
  for each pixel $p_i \in$ YcbcrImg **do**
    Cb←cb component of pixel p_i
    Cr←cr component of pixel p_i
    $x_i \leftarrow \begin{pmatrix} Cb - CbMean \\ Cr - CrMean \end{pmatrix}$
    skinLikelihood(p_i) ← $\exp(-0.5 \times x_i^T \times C^{-1} \times x_i)$
  end for
  DetectedEdge← EdgeDetection(skinLikelihood)
  BinarySkin← GlobalBinarization(skinLikelihood)
  EnhanceSkin← BinarySkin + DetectedEdge
  FilledSkin←MorphologicalFilling(EnhanceSkin)
  ErodedSkin←MorphologicalErosion(FilledSkin)
  DilatedSkin←MorphologicalDilation(ErodedSkin)
  DetectedPalm←CircularAveragingFilter(DilatedSkin)
end while

Algorithm 1. Algorithm for palm detection based on skin color model

accurate ROI. There are various valley detection methods that have been proposed in earlier studies. Chih-Lung Lin *et al.*[10] used the euclidean distance between the midpoint of the bottom margin of palm and boundary pixels of the palm have been computed and then four local minima of the euclidean distance distribution diagram is used to find the valley point's location. Goh Kah Ong Michael *et al.*[6], proposed to use the number of pixels around each boundary pixels have been considered in three iterations based on some condition on the number of non-hand pixels in each iteration. Finally a line drawn outward in non hand pixels and if it does not cross any hand region, then the boundary pixel has been considered as valley point. Here we propose a novel VP detection algorithm (see Algorithm 2) to extract the candidate key points of the palm. We draw a number of circles around the boundary of palm image at the distance of r (Here we divide the total number of boundary pixels by number of circles we want to draw around the boundary and using the resultant value as radius r of the circles) from center of previous circle. Then for each circle we count the number of white pixels lying on the circumference of a circle. These white pixels are nothing but pixels lying within the binary image of palm. The centers of circles having number of white pixels on its circumference greater than the threshold is taken as the valley points and the centers of circles having number of white pixels less than some threshold is the finger tips.

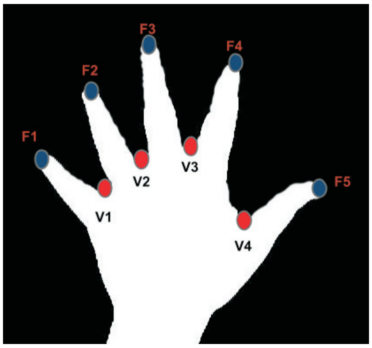

Fig. 3. The red dots ($V1$, $V2$, $V3$, $V4$) are the valley points and the blue dots ($F1$, $F2$, $F3$, $F4$, $F5$) are finger tips

The algorithm for proposed Valley Points Detection method can be described as follow:

```
Input:   BinaryPalm(binary segmented palm image)
Output:  ValleyPoints(Set of Valley points of the palm)
BoundaryCircles←DrawBoundaryCircle(BinaryPalm)
for each circles c_i ∈ BoundaryCircles do
    CicumferencePixels←BoundaryPixels(c_i)
    for each pixels p_j ∈ CicumferencePixels do
        if p_j=1 then
            WhitePixels←WhitePixels+1
        end if
        if WhitePixels> threshold_1 then
            ValleyPoints← centre(c_i)
        else if WhitePixels< threshold_2 then
            FingerTips← centre(c_i)
        end if
    end for
end for
```

Algorithm 2. Valley points detection algorithm

The results of proposed approach shown in Fig. 4 verifies its precision and accuracy. The time complexity of the proposed algorithm is $O(m \times n)$ where m is the total number of boundary pixels around the palm and n is the total number of pixels on the circumference of a circle around each boundary pixel.

4.3 Scaling effect

After getting segmented palm region the Convex Hull is drawn over the boundary of palm. The Convex Hull is the smallest convex polygon containing all the points in two dimension space. Graham scan[11] has proposed a much more efficient algorithm for computing Convex Hull with $O(n \log n)$ time complexity. The Convex Hull has many real-time practical applications[12]. Here we use the area of the convex hull to accepted or rejected the video frame based on some threshold area. Since the users have no restriction for keeping their hands at a fixed distance from the camera device. The user may keep their hands at varying distance from the camera and this would degrade the quality of palmprint image. As far we move our hand from the camera the quality of palmprint image goes on degrading. As a result the texture features that we can get from palmprint becomes less appealing and hazy. So there should be a proper balance between the flexibility for user and the quality of palmprint image by taking threshold area of the palm into the consideration. The area of a polygon, formed by the convex hull around the boundary of the palm image is used to guide the user to put their palm at right distance from camera based on some threshold area. Along with some threshold area, we should use number of skin pixels within the convex hull to get a better approximation of distance. The convex hull is shown in Fig. 5 with green color polygon and its area and skin pixels in yellow text.

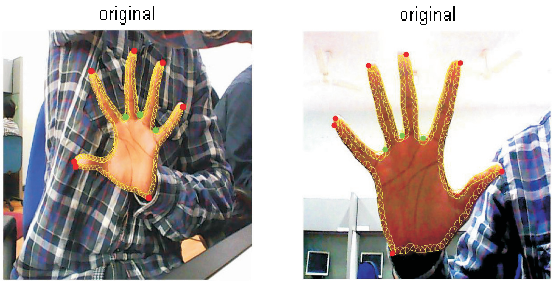

Fig. 4. The red dots show finger tips and the green dots show valley points. The small yellow dots on the circumference of circles shows detected white pixels.

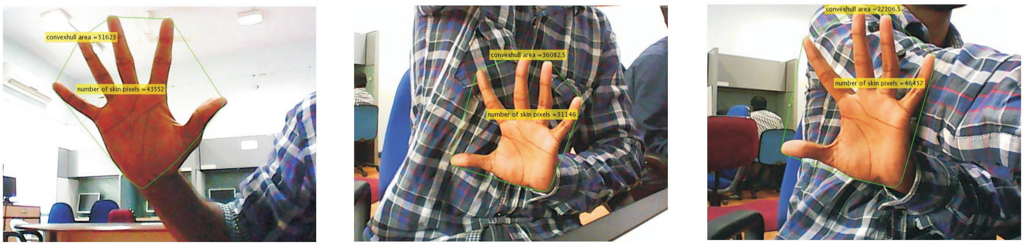

Fig. 5. The convex hull is shown with green color polygon.

4.4 Palm orientations

Since the users are free to put their palm in any orientations, so we should need to determine the orientation of palm before ROIs are extracted as it should affect the performance verification of the system. In order to deal with the palm orientation we use the angle of rotation (θ) and discard the image (frame) if it is greater than certain threshold rotation angle θ_τ. After the detection of valley points $V1$, $V2$, $V3$ and $V4$ we should calculate the angle of rotation (θ) using the slope of the line drawn between the points $P1$ and $P2$ (see Fig. 9). Again, after extraction of ROI from the palm we use the same angle θ to transform the ROI to the reference coordinate system. The angle of rotation (θ) can be computed by Eq. (3) given below:

$$\theta = \tan^{-1}(x2 - x1, y2 - y1) \times 180/\pi \tag{3}$$

The Fig. 6 shown below shows the rotation along the line joining coordinates of points $P1(x1, y1)$ and $P2(x2, y2)$ and vertical y-axis.

4.5 Region of interest location

In earlier studies various ROI extraction methods have been proposed. David Zhang *et al.*,[5] proposed a method to extract static fixed size ROI by drawing the reference line using the two valley points $V1$ and $\upsilon 3$ (between index finger and middle finger, and little finger and ring finger) and then extracting the fixed size ROI at some distance from perpendicular bisector of the reference line. Tee Connie *et al.*,[13] extract ROI by extending the line joining the two valley points $V1$ and $V3$ to touch the extreme ends of the palm and then considers the two middle points of the intersections of both edges of palm. These two middle points are then used to draw the square ROI. G. S. Badrinath *et al.*,[14] suggested to extract the ROI by drawing the two lines from these two valley points $V1$ and $V3$ at angles 45° and 60° respectively with respect to the reference line to touch the extreme end of the palm and then considers the two middle points of that line as the basis for drawing square ROI. Kalluri *et al.*[15] proposed another ROI extraction method based on the Y-coordinate information of border pixels and maximization algorithm extract maximum ROI. Here we

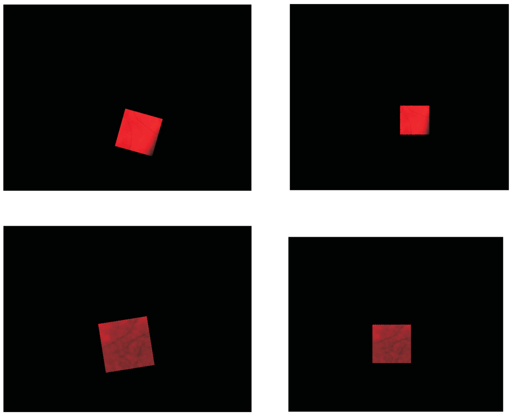

Fig. 6. The original image(left) and rotated image(right)

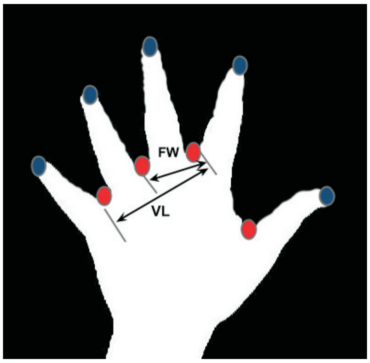

Fig. 7. Above figure showing finger width (FW) and valley distance (VL)

proposed a new dynamic ROIs extraction method to acquire the dynamic and maximum ROIs from real time video frames of a camera. After obtaining the finger's valleys, $V1$, $V2$, $V3$, and $V4$, we use the length VL 7(distance between $V1$, $V3$) to draw square ROI. We use finger width FW (distance between $V2$, $V3$ see Fig. 7) which is almost common for every finger to get maximum ROI by adding one third of FW to VL to both ends. Using coordinate geometric with coordinates of $P1(x1, y1)$ and $P2(x2, y2)$ we finds the coordinates of other two points of square (see Fig. 9). Based on the above information, the outline for dynamic ROIs extraction methods can be described as follow:

1. Find the valley points $V1$, $V2$, $V3$ and $V4$ of the palm using valley detection algorithm.
2. Find the coordinates $K1(i1, j1)$, $K2(i2, j2)$ and $K3(i3, j3)$ of the valley points $V1$, $V2$ and $V3$ respectively.
3. Calculate width of finger (FW) by (4) which is roughly the distance between $K2(i2, j2)$ and $K3(i3, j3)$.

$$\text{Finger width (FW)} = \sqrt{(i2 - i3)^2 + (j2 - j3)^2} \tag{4}$$

4. Update the coordinates of $K1$ and $K3$ by (5) to get points $P1(x1, y1)$ and $P2(x2, y2)$ respectively.

$$\begin{aligned} x1 &= i1 + FW/3 \\ y1 &= j1 + FW/3 \\ x2 &= i3 + FW/3 \\ y2 &= j3 - FW/3 \end{aligned} \tag{5}$$

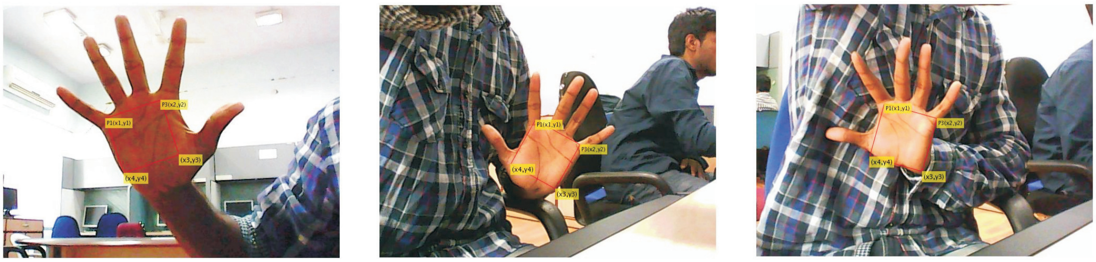

Fig. 8. The images are from web camera in touchless mode and the region of interest shown with red square.

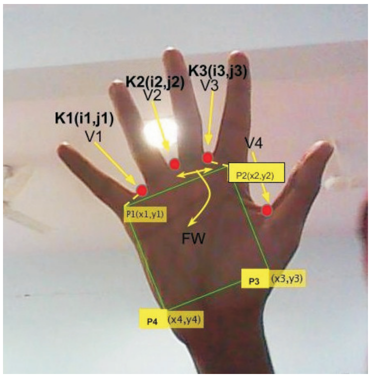

Fig. 9. Outline of ROI extraction

5. Find coordinates of other two points of square i.e $P3(x3, y3)$ and $P4(x4, y4)$ by (6)

$$
\begin{aligned}
a &= \text{absolute\_value}((y1 - y2)/(x1 - x2)) \\
b &= 1 \\
len &= \sqrt{(x2 - x1)^2 + (y2 - y1)^2} \\
ab &= \sqrt{a^2 + b^2} \\
x3 &= x2 + a \times len/ab \\
y3 &= y2 + b \times len/ab \\
x4 &= x1 + a \times len/ab \\
y4 &= y1 + b \times len/ab
\end{aligned} \tag{6}
$$

The region of interest obtained from above method is shown in Fig. 8 with red square.

5. Experimental Setup and Results

In our experiment, a standard PC with Intel Core i3 CPU (2.93 GHz) and 2048 MB random access memory is used. The program is developed using Matlab 2014. The image acquisition, skin-color model, rotation, scaling and ROI extraction modules, are written in Matlab. The proposed methodology is tested on IIT Delhi Touchless database[16] and the result is shown in Fig. 10. The IIT Delhi touchless database of palmprint is a publicly available database.

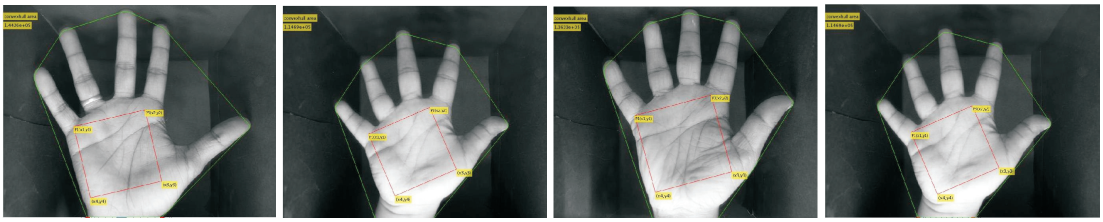

Fig. 10. The images are from IIT Delhi touchless database with the region of interest shown with red dotted square.

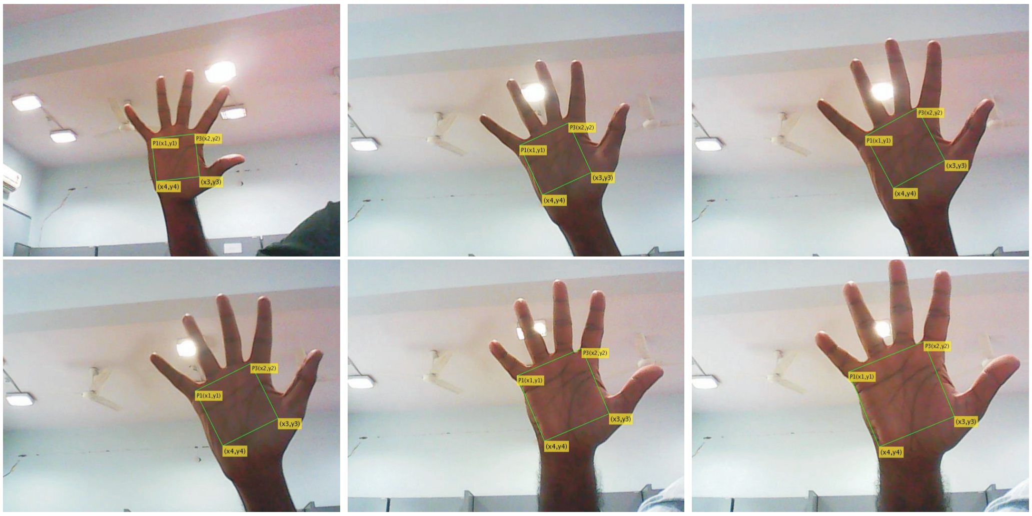

Fig. 11. ROIs tracked and shown with green color.

This database has been acquired using a simple and touchless imaging setup. All the images are collected in the indoor environment with background and illumination are quiet controlled. These images are acquired in varying hand pose and higher image scale variations. The resolution of these images is 800×600 pixels and all these images are available in bitmap format. We further experimented online in video sequence from web camera at 30 fps with resolution of 640×480 with different volunteer to test the efficacy of proposed building blocks for touchless palmprint registration. Figure 11, shows ROI of a hand being tracked at different distances, orientation and light conditions.

6. Conclusions and Future Works

6.1 Conclusions

This paper presents a new valley points detection algorithm and modified methods to get maximum ROI based on finger width. The proposed palmprint registration system can tolerate the scaling effect by use of an area of the polygon formed by the boundary of palm. It can tolerate the rotation of palmprint image in plane Surface and the effect of background images using a Gaussian skin color model.

6.2 Future works

Based on the essential building blocks discussed in section 4, we can develop a Touchless palmprint Registration System which would acquire palmprint images from video frames by using low-resolution CMOS web camera. The schematic diagram of the proposed system is shown in Fig. 12. The frame acquired by camera device can be fed to Gaussian skin color model for detecting palm even in complex background and varying illumination. If the frame is

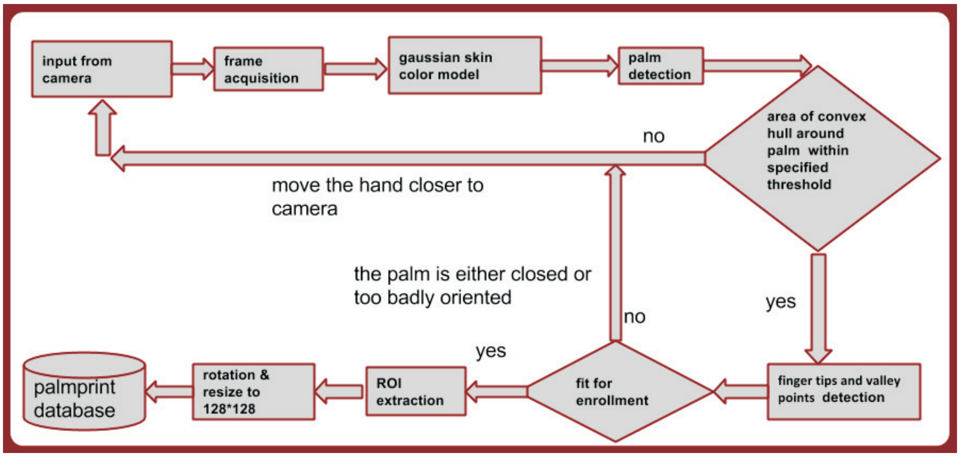

Fig. 12. The schematic block diagram of proposed touchless palmprint registration system

accepted then finger tips and valley points are determined. Based on number of finger tip points we can further discard the frame if not fit for further processing. Again, if the palm orientation is not within acceptable range, we discard the frame. After that, ROIs are extracted from the palm. Since these ROIs are taken from a low resolution camera so print feature like wrinkles, principle lines, minutiae points, datum points, ridges and crease points that contribute to texture are not good. So these ROIs are to be further preprocessed to eliminate various noises. Since, the dynamic ROIs are extracted at different distances and different orientations of the hand. So these ROIs are rotated and resized to standard 128×128 size then stored in the database for later use.

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